the difference in properties, mixtures of antioxidants and synergists are often used.

The prevention of oxidation in animal products such as fish, meats, and poultry, is of great economic importance, but unfortunately success in this field has been limited, probably because of the poor contact of the antioxidant with the fat and the presence of moisture. The oxidative discoloration of many fruits and vegetables has been retarded by treatment with ascorbic acid. This compound may play three roles in retarding oxidation. They are its action as a reducing agent, acid, and synergist. The discoloration of canned mushrooms has been reduced and the flavor improved by the addition of ascorbic and citric acids.

Antioxidants are used to prevent oxidation of the vitamins. α-Tocopherol (vitamin E) and ascorbic acid (vitamin C) are often added to prevent oxidation of vitamin A.

New antioxidants are being tailormade to meet certain problems in food preservation.

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Cross-references: *Additives, Foods, Oxidation*

ANTIOZONANTS

Antiozonants, sometimes referred to as "antioxidants" and as "sunproofing agents," impart to natural rubber and synthetic rubber compounds various degrees of resistance to atmospheric ozone. The cracking of rubber on exposure to the atmosphere is caused by two separate mechanisms. Light-activated oxidation results in a resinification of the surface; the surface, being brittle, breaks in an irregular criss-cross pattern as a result of surface shrinkage or movement caused by contraction and expansion or other disturbances. The second mechanism is the attack of ozone on strained rubber which takes place in the dark as well as in light and results in cracks running at right angles to the strain. A complex strain pattern will result in a complex crack pattern, but cracking resulting from ozone can usually be identified as being distinct from cracking due to light-activated oxidation.

The atmospheric ozone effect is very often visible in a matter of days, and severe, damaging cracks may develop in weeks. Its action is progressive and once started is not reduced or halted until stress relaxation occurs or the ozone concentration is reduced.

The light-activated oxidation effect is a surface effect which tends to lend protection to the underlying material and is often not particularly disruptive of the rubber's useful life, providing that the article is not thin in cross-section and a high ratio of volume to surface exists.

Petroleum waxes have come to be known as "sunproofing agents" because the cracks in rubber caused by ozone were formerly considered by many to result from exposure of rubber to the sun, and the addition of waxes to rubber compounds tends to reduce or prevent this type of cracking. Waxes are often still referred to in this manner. They function by being incorporated in the rubber in amounts exceeding their solubilities in the compound so that they migrate to the surface (bloom). This surface layer prevents the ozone from contacting the rubber and thus ozone cracking does not result. A small amount of wax may be more harmful than beneficial, as the surface is spottily coated with wax and where the wax is thin or missing, ozone attack results in large, deep cracks. With no wax, the surface is often uniformly covered with small, shallow cracks which stress-relieve the surface as they form. Wax blooms are often protective for static exposure but if such blooms are lacking in adhesion or flexibility, they will rupture or break away from the rubber surface during dynamic use. This again results in larger and deeper cracks than if no wax had been incorporated.

Waxes used for imparting ozone protection are usually mixtures of microcrystalline and amorphous waxes, some of which are designed to form flexible blooms at winter atmospheric temperatures and yet produce sufficient blooms at the higher temperatures of summer. As temperature rises, the solubility of waxes in polymers increases and thus less wax is available to form the protective bloom. Higher quantities of wax generally help at elevated temperatures, but they may form heavy, crusty, undesirable blooms at normal room temperatures. Paraffin is often effective, but paraffin blooms are generally brittle.

Certain antioxidants, often of the type which provide resistance to flex cracking, also impart added ozone resistance. Some of these antioxidants, when used as antiozonants, must be used in concentrations as high as five parts on the rubber. Often some wax is desirable in the compound to assist in carrying the antiozonant to the rubber surface. Some of these materials also impart dynamic protection which is of concern in such things as tire sidewalls. Representative materials are: (1) secondary aromatic amines such as N,N'-dioctyl-paraphenylenediamine and diphenyl-paraphenylenediamine, and (2) quinoline derivatives such as 6-ethoxy-1,2-dihydro-2,2,4-trimethylquinoline and polymerized 1,2-dihydro-2,2,4-trimethylquinoline.

Certain furane derivatives have also been shown to have antiozonant properties; and for many years it has been known that vulcanized oils, generally known as factice, when used in relatively high loadings, impart ozone resistance, but at the expense of lowering most physical properties. All the materials referred to above are properly called antiozonants as they protect from ozone, as already described.

Reduction of light-activated oxidation effects can be obtained in two ways. Incorporation of opaque ingredients in the rubber will lessen penetration of ultraviolet energy into the rubber and thus reduce the thickness of the oxidized layer. Carbon blacks, certain colors and titanium dioxide act as light shields in this manner. Black compounds resist light-activated oxidation fairly well, but nonblack compounds will generally surface-deteriorate on exposure. The incorporation of antioxidants in rubber compounds will reduce light-activated oxidation effects to some extent. The use of nickel dibutyl dithiocarbamate appears